PROCESS FOR ASSEMBLY OF METALLIC PARTS USING A METALLIC POWDER HEATED BY INDUCTION

Field of the invention

The invention is related to the assembly of metallic parts with filler metal and is somewhat similar to brazing. The induction heating process is used.

Prior art and problem solved

For the assembly of two metallic parts made of the same material or a different material by means of a metallic powder placed between these two parts, the objective is to heat the said metallic powder in order to temporarily transform it into a molten material to become a rigid connecting element between the two parts when it has cooled. This is a means of brazing that consists of using a metallic powder in which the melting temperature is below the melting temperature of the two parts to be assembled. Furthermore, brazing processes are known that make use of induction heating using a filler metal in powder form. Many metals may be assembled in this manner, particularly copper or stainless steel, using appropriate filler materials. For copper, alloys with a high content of copper and silver, or zinc copper are usually used. The brazing temperature is of the order of 700 to 800°C. For stainless steel, filler alloys are based on silver, copper, nickel or gold. Brazing is done at between 700 and 1100°C. The various filler materials in powder form are often mixed with a flux. In all these cases, the filler material in powder form is made of a

material different from the material from which the two parts to be assembled are made, and its melting temperature is below the melting temperature of these two parts.

Furthermore, the use of powders of the same nature as the parts to be assembled is known for applications with a significant connecting thickness (of the order of several millimetres). The base metal powder is always accompanied by a filler material for which the melting temperature is below the melting temperature of the base metal. Pressure is always applied during the brazing cycle in order to encourage elimination of pores at the connection (see US patent 5 812 925).

Furthermore, it is known that two parts of the same nature can be assembled together, for example two parts made of aluminium by using a powder made of a metallic constituent with a melting temperature that is higher than the melting temperature of the parts, for example in the case of an aluminium assembly, a mix of silicon and a potassium fluoroaluminate flux. In this case, the liquid phase is still achieved at a temperature lower than the melting temperature of the two parts, due to diffusion phenomena between the powder and the parts that cause formation of a phase at a melting temperature lower than the temperature of the parts.

There is another assembly technique, namely diffusion welding. But in this process, the powder inserted between the two metallic surfaces does not change to the liquid state during assembly. It is a solid state welding process, in which a bond is formed by diffusion of a powder placed between metallic surfaces in contact by application of a pressure at

high temperature for a sufficiently long time without the addition of any chemical element.

Summary of the invention

The main purpose of the invention is a process for the assembly of two metallic parts by melting a filler material, characterized in that it consists of:

- using induction heating, and
- using a powder with a melting temperature higher than or equal to the melting temperature of the two parts to be assembled when they are of the same nature, or higher than or equal to the melting temperature of the part with the lowest melting temperature for parts with different natures, as a filler material, in order to make the assembly without a phase being formed at a melting temperature lower than the temperature of the two parts. In particular, the combination of these two means avoids the need to use a chemical filler element and there is no need to exert a pressure at high temperature to make the bond.

In a preferred embodiment of the invention, the two parts are of the same nature and the powder is made of the same material as the material from which the parts are made, the melting temperature of the powder and the parts being the same.

It is possible to compact the powder before it is inserted between the two parts.

Detailed description of an embodiment of the invention

The invention is somewhat similar to induction brazing, but the following essential point makes it different.

The filler material is a metallic powder, with a melting temperature higher than or equal to the melting temperature of the two parts to be assembled in the case of an assembly of parts of the same material, or higher than or equal to the melting temperature of the part with the lowest melting temperature for parts with different natures.

The combined use of a metallic filler metal powder with induction heating introduces specific conditions during the temperature rise of this powder, such that the powder is melted but the parts are not melted. The principle of induction heating of homogeneous metallic parts is based on LENZ's law that states that any electrical conducting substance subjected to a variable magnetic field will be a source of induced currents. These currents dissipate heat due to the Joule effect, which causes an increase in the temperature of the material in which it is circulating. The penetration depth of the induced currents is variable depending on the frequency of the magnetic field, and on the physical properties of the parts, such as the magnetic permeability and the electrical resistivity. In the case of a metallic powder, induction heating of a metallic powder implies a much more complex distribution of induced currents than would occur in the same material in a dense part since the medium consisting of a metallic powder is not homogeneous. Furthermore, the presence and nature of oxide films at the surface of particles has an influence on

circulation of induced currents in the powder. Therefore, the increase in temperature due to the circulation of induced currents is very different in the powder and in the parts.

The observed phenomenon is due to the fact that inductive coupling may be more efficient for powder than for metallic parts. Therefore, this results in a higher temperature increase in the powder than in the dense material.

It is necessary to make a clear distinction between the powder in its initial state, which is not the source of induced currents, and the powder when metallic contacts between particles are set up and induced currents can circulate. In the initial state, in other words at ambient temperature, the coupling conditions are usually unfavourable for powder since the electrical resistivity of the powders used is very high, due to the presence of a surface layer of oxide on the particles. However during heating, the powder temperature increases due to heat transfers with the dense parts. In this case, the oxide surface layers that can exist on the surface of particles of the powder change nature or are eliminated. Furthermore, metallic contacts between the particles become increasingly numerous and their surface areas increase under the effect of temperature. Therefore, the manner in which induced currents circulate in the powder changes significantly during heating, which results in a large variation of the efficiency of heating. When these conditions are satisfied for the powder, its temperature may be higher than the temperature of the dense parts. Therefore, it is possible to melt the powder without melting the parts.

The efficiency of induction heating is different depending on whether the powder particles are in metallic contact or are electrically isolated from each other by oxide films.

Thus, when contacts between particles are made before the heating cycle, using hot-formed powder preforms, the induced currents develop at the periphery of the granular medium and, for example, facilitate the assembly of tubular-shaped parts.

The behaviour is very different in the case in which metallic contacts between filler metal particles are not created before the assembly. The formation of the first contacts and circulation of very intense induced currents cause very large voltage variations within the granular medium. Values of the "breakdown voltage" can be reached at contacts covered with insulating films. In this case, melting at these contacts takes place quickly and extends throughout the granular medium.

The powder can also be compacted in advance, in order to facilitate its placement between the parts to be assembled.

The assembly is obtained by using the normal wetting, capillarity phenomena in the same way as for brazing.

The assembly quality depends on the materials, with different parameters used, the initial characteristics of the powder and the temperature cycle.

The metallic parts and the powder can be composed of a pure metal or an alloy.

The powder may be composed of a mix of particles of different metals.

The preferred application of this process applies to metallic parts and powder made of the same material.

The induction heating must stop when all the powder has melted, so that the assembly can be made when all the powder is in the liquid state.

The fundamental steps in the process are as follows.

- Add a thin layer of metallic powder between two dense metallic parts to be assembled together.

- Heat the powder and dense metallic parts over a limited area by induction heating, preferably close to the joint to be made. Therefore, remember that the powder is initially heated due to the presence of dense metallic parts, these parts being the source of induced currents which explain the reason for the increase in their temperature. Heat exchanges then take place between the parts and the powder. Increasingly numerous metallic contacts are set up between the particles under the effect of this heating. When they are sufficiently developed, induced currents can circulate between powder particles. Consequently, the presence of dense parts is fundamental to enable the creation of these contacts and induction heating of the powder.

- Melting of the powder because inductive heating is more efficient than on dense metallic parts, therefore the temperature of the powder is higher than the temperature of the parts.

- Stop induction heating to cool the assembly, and consequently to achieve solidification.

One example consists of assembling copper pellets with copper powder. The two pellets are cylindrical with a diameter of 20 mm and a height of 5 mm. A few

grams of copper powder are sandwiched between the two copper pellets, to obtain a thin layer of copper a few micrometers thick distributed as uniformly as possible over the entire area of the pellets. The size of the particle is of the order of 40 micrometers. Induction heating is achieved using a high frequency generator with a power of 25 kW. The induction coil used is an induction coil with two turns, with a diameter of 56 mm and a height of 10 mm. The assembly is made under a secondary vacuum at a frequency of 155 kHz.

In this case, the following detailed operations are performed.

- Place the two copper pellets and powder assembly in the induction coil inside a vacuum chamber.
- Close the vacuum chamber.
- Create a primary vacuum.
- Create a secondary vacuum.
- Switch the field coil generator power on.
- Adjust the power set values.
- Switch the high voltage on.
- Induction heating of the pellets and powder assembly.
- Melt the powder.
- Switch the high voltage off.
- Cool under vacuum.
- Open the vacuum chamber.
- Take the assembled assembly out of the chamber.

Another example consists of assembling Z2CN18-10 stainless steel pellets, commonly called AiSi 304 pellets, with Z12CN25-20 stainless steel powder, commonly called AiSi 310. The test results show that the mechanical strength of the assemblies is of the order of 70% of the ultimate strength of the reference

material and elongation at failure is 90% of the elongation at failure of the reference material.

The process and operating method are the same as for copper.

Advantages of the invention

This process can be applied to different metals and alloys.

It has the same advantages as high temperature brazing since it:

- avoids parts to be assembled changing to the liquid state. This can prevent some metallurgical problems such as the appearance of cracks;

- enables use of the assembled assemblies at high temperature;

Furthermore, the fact that parts are assembled using powder made of exactly the same material can limit impurities during assembly, which is very useful for parts used in a corrosive environment. Furthermore, there is no deterioration of electrical properties at the joint. Therefore, this process can advantageously be used for connections.

Furthermore, the device preferably uses a high-frequency generator as an induction heating source. Consequently, this technique is very easy to implement and can be used directly to replace traditional induction brazing for improved performances.